

Liquid Argon for Direct Detection of Dark Matter

Work and Plans at Fermilab



Why Liquid Argon

What are the technical issues

Why and What at Fermilab



Why Liquid Argon for Dark Matter Detection:

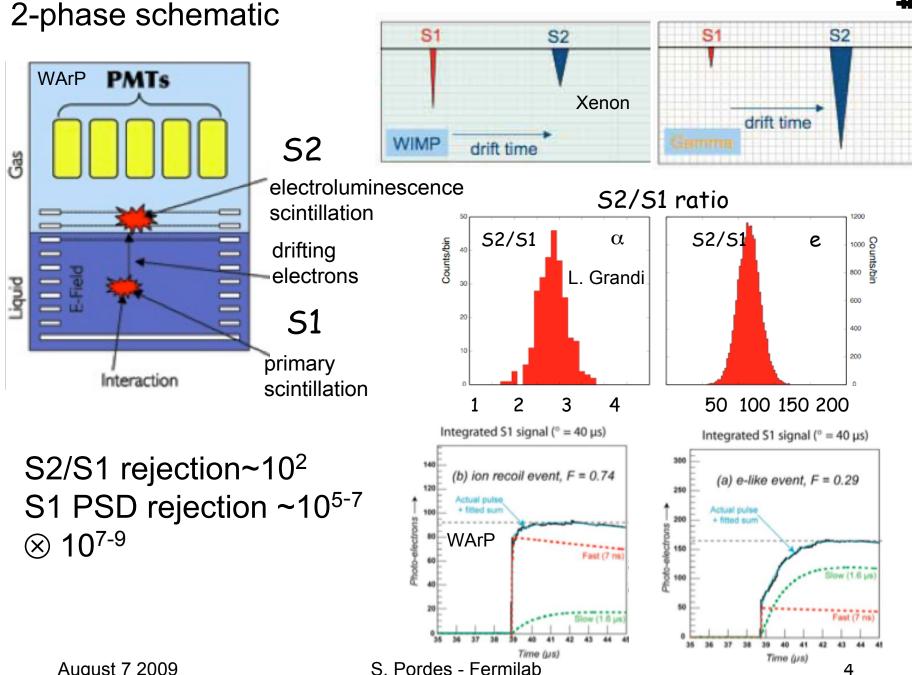
Signature of WIMP interaction: Nucleus recoiling from WIMP

Experiment challenge is to reject backgrounds to DM signal and to have sufficient target-mass. Backgrounds come from photons (low dE/dx) and neutrons (high dE/dx)

Noble Liquids

- radiation produces free charges and free photons
- charge to light ratio depends on density of energy deposition
- scintillation light has two components with different decay times whose intensity ratio depends on density of energy deposition Argon has particularly powerful separation here (PSD)
- Argon allows one to exploit both ionization/light ratio and scintillation time structure for maximum discrimination.





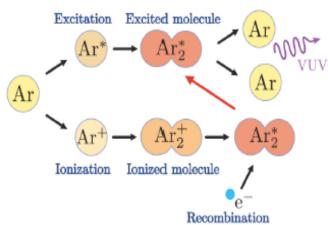
August 7 2009

S. Pordes - Fermilab

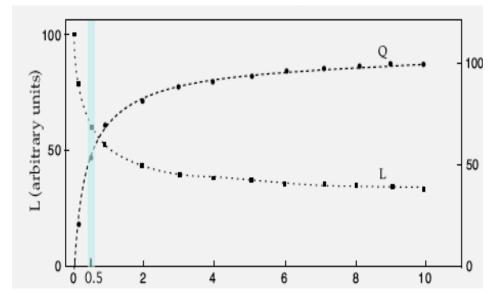
Argon Light and Charge and Stuff



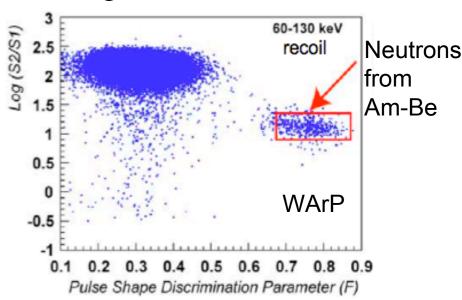


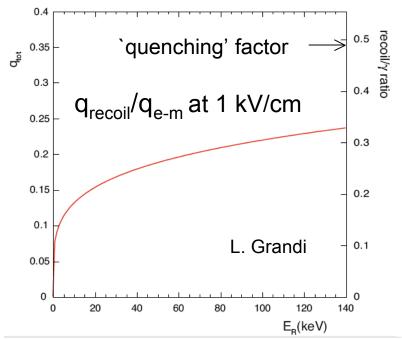


charge (Q) and light (L) yield vs electric field



5000 e/mm and 2000 phot./mm at 0.5 kV/cm (mip)







From the MAX collaboration S4 proposal

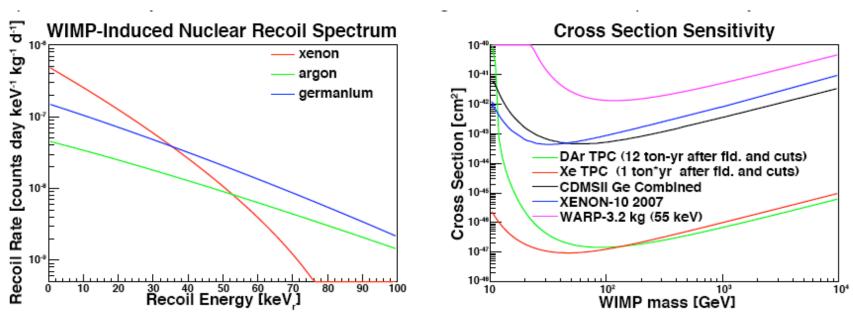


FIG. 1: (a) Nuclear recoil spectrum for Ar and Xe targets ($M_{\chi}=100\,\mathrm{GeV}$ and $\sigma_{\chi\mathrm{N}}=10^{-47}\,\mathrm{cm}^2$). (b) Physics reach of the 5.0 ton DAr TPC (5-yr run, 12 ton-yr exposure after fiducial and analysis cuts) and of the 2.4 ton Xe TPC (2-yr run, 1 ton-yr exposure after fiducial and analysis cuts) presented in this proposal, compared with the limits achieved by CDMS, Xenon, Warp, and Zeplin [4, 5, 18, 19, 25].

Argon and Xenon components of MAX detectors - Argon mass set by DUSEL access



What the technical Issues for Multi-ton Argon detector:

Chemical purity of Argon to allow electron drift (10's ppt O₂)

Chemical purity of Argon to allow light propagation(<ppm N₂)

HV feedthroughs (>100 kV) in Argon gas

TPC design

Data Acquisition

Cryogenics (and associated safety issues)

Detector Materials Qualification

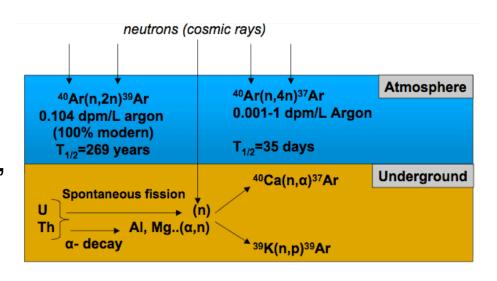
Shielding from environment radiation

Radio-purity of detector material

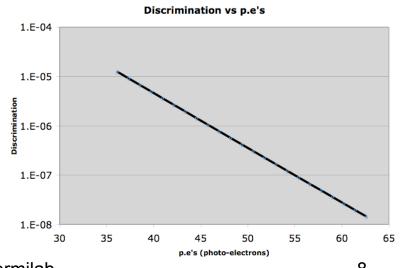


What: Critical Technical Issues:

³⁹Ar in atmospheric Argon (1 Bq/kg) - this is a potential showstopper: β with 565 keV endpoint, limits useful scale to ~0.5 ton (1 ton gives 3 x 10¹⁰ decays/yr) ->underground sources



Light detection efficiency
Photo-electrons/keV feeds into
threshold (discrimination power)
and thus sensitive cross section.
-> investigate photo-detectors
& optics





Why and What at Fermilab:

Interest among scientific staff

Appropriate technical expertise - in cryogenics, electronics

Synergies with Neutrino Program (prompted idea)



Why and What: Fermilab

Technical Issues for Multi-ton Argon detector:

Chemical purity of Argon to allow electron drift (10's ppt O2 equivalent),

Chemical purity of Argon to allow light propagation

HV feedthroughs (>100 kV) in Argon gas

TPC design

Data Acquisition

Cryogenics (and associated safety issues)

Detector Materials Qualification

Shielding from environment radiation

Radio-purity of detector materials



Why and What Fermilab

Technical Issues for Multi-ton Argon detector:

Chemical purity of Argon to allow electron drift (10's ppt O2 equivalent), *(neutrino and DM)*

Chemical purity of Argon to allow light propagation (DM)

HV feedthroughs (>100 kV) in Argon gas (neutrino and DM)

TPC design (neutrino and DM)

Data Acquisition (neutrino and DM)

Cryogenics (and associated safety issues) (neutrino and DM)

Detector Materials Qualification (neutrino and DM)

Shielding from environment radiation (DM)

Radio-purity of detector materials (DM)



Learning how to do what has been done by others (cryogenics, purification, purity monitoring, electronics readout (MSU) - all are now designed and built in the US)

New stuff - our own filter systems, material test systems, the effect of H₂0, coating fibers with TPB (MIT)

FERMILAB-TM-2384-E: efficiency of slow purging to remove atmosphere to ppm levels

A regenerable filter for liquid argon purification

A. Curioni b, B.T. Fleming b, W. Jaskierny a, C. Kendziora a, J. Krider a, S. Pordes a, M. Soderberg b, J. Spitz b,*, T. Tope a, T. Wongjirad b

A system to test the effect of materials on electron drift lifetime in liquid argon and the effect of water

NIM-A

R. Andrews, W. Jaskierny, H. Jöstlein, C. Kendziora, S. Pordes*, T. Tope

Particle Physics Division, Fermi National Accelerator Laboratory, Batavia, IL 60510, USA

^a Particle Physics Division, Fermi National Accelerator Laboratory, Chicago, IL, USA

b Department of Physics, Yale University, New Haven, CT, USA

Liquid Argon Setup for Materials Testing and TPC Readout

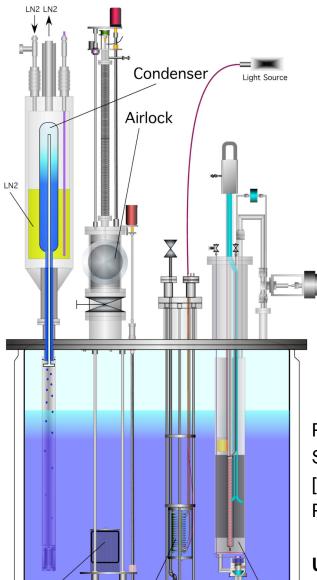




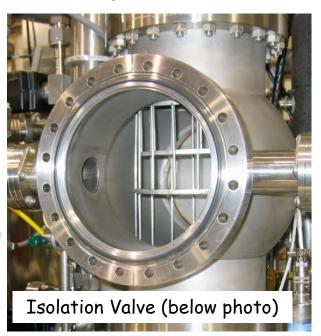
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Materials Test System





insertion of materials without exposure to vacuum



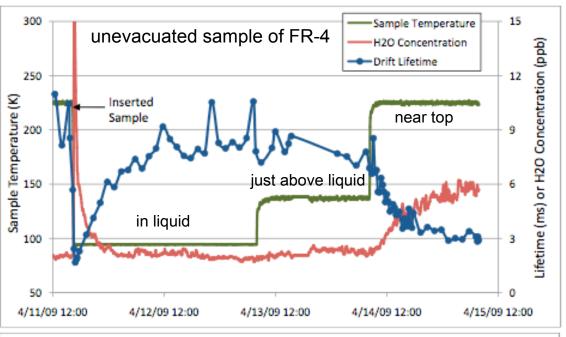
Put materials in Sample Cage in the Argon Lock Seal the Argon Lock (open in photograph). [Evacuate the Argon Lock (or not).] Purge with pure argon gas (available from the cryostat).

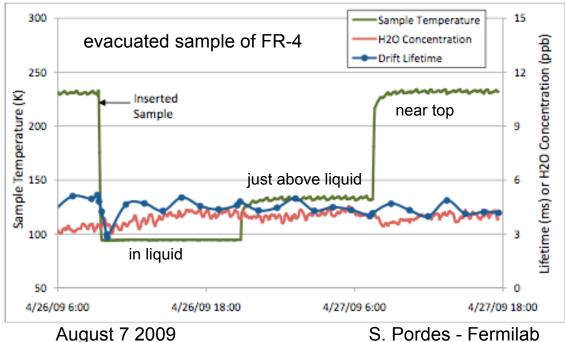
Unique system

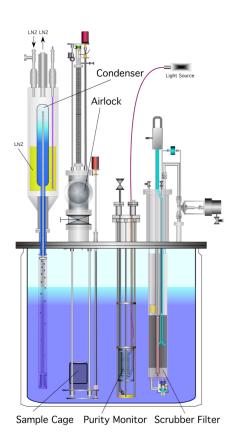




Data from Materials Test System







Showing effect of water concentration on drift-lifetime - we see the same effect with all materials we have tested. H20 is perfect marker.



What for Dark Matter (only) at Fermilab:

Context:

DArCSIDE Collaboration*



- characterization of depleted Argon
- preparation of 20 kg detector
 - -->treat the Most Urgent Issues (39Ar, light collection)
- preparation for next step towards MAX

Galbiati spending sabbatical year at Fermilab

Participation in S4 proposal, MAX, 5 ton Argon, 2 ton Xenon

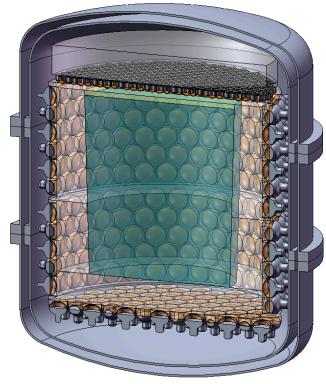
* Depleted Argon Cryogenic Scintillation & Ionization Detector



What: MAX collaboration S4 Proposal for engineering of a 5 ton Argon and 2 ton Xenon detector at DUSEL



Fermilab staff in important positions in electronics, cryogenics, and purification for the LAr detector



Fermilab Directorate provided letter of support. NSF will fund



Argon Detector Concept

 Largest diameter cryostat that will fit down DUSEL elevator.

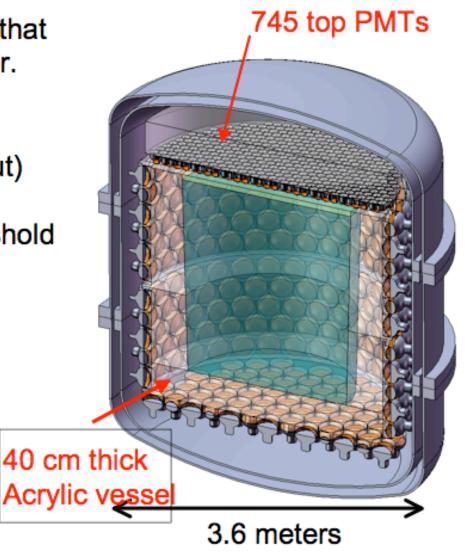
5 tons depleted argon
 (2.6 tons after fiducial cut)

30 keV recoil energy threshold

~ 2 cm position resolution

 0.5 background events expected in 5-year run.

3 order of magnitude improvement over present CDMS/ XENON sensitivity





1.1.3.1 Xe HV interconnects	Element	Work package	Definition	Responsible	Class
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1.0.2 Nat TPC Detector Manager Tajiri (COL) C	1.	Dark Matter Detectors		Parsells (PRI)	С
1.0.2 Xe TPC			Detector Manager		_
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1.1.8 Calibration	1.1.7.1	Xe specific fluids	Interface to storage, fill, & empty systems	Giboni (COL)	XE
11.8.1 Xe Specific Calibration	1.1.7.2	Ar specific fluids	Interfaces to storage, fill, & empty systems	Pordes (FNAL)	AR
1.1.8.2 Ar Specific Calibration Light & charge sources for calibration data Monroe (MIT) AR 1.1.9.1 TPC materials Radioactivity budgets Pocar (UMA) C 1.1.9.2 TPC materials Radon plate-out Monroe (MIT) C 1.1.9.3 TPC materials Radon plate-out Monroe (MIT) C 1.1.9.3 TPC materials Radon plate-out Monroe (MIT) C 1.1.9.3 TPC materials Radon emanation Pocar (UMA) C 1.1.0.1 Xe TPC integration Mechanical & electrical systems integration Tajiri (COL) XE 1.1.0.2 Ar TPC integration Mechanical & electrical systems integration Tajiri (COL) XE 1.1.0.2 Ar TPC integration Mechanical & electrical systems integration Sands (PRI-TEM) AR 1.2.1 Ar liner mechanical Specifications & method of construction Martoff (TEM) AR 1.2.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 SF PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.2 SF PMTs support Mechanical support structure Wang (UCLA) C 1.3.5.2 SF PMTs support Mechanical support structure Wang (UCLA) C 1.3.5.2 SF PMTs support Mechanical support structure Wang (UCLA) C 1.3.5.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS)	1.1.8	Calibration	Light & charge sources for calibration data	Monroe (MIT)	С
11.9.1 TPC materials Radioactivity budgets Pocar (UMA) C 11.9.2 TPC materials Radon plate-out Monroe (MIT) C 11.9.3 TPC materials Radon emanation Pocar (UMA) C 11.9.3 TPC materials Radon emanation Pocar (UMA) C 11.10.1 Xe TPC integration Mechanical & electrical systems integration Tajiri (COL) XE 11.10.2 Ar TPC integration Mechanical & electrical systems integration Sands (PRI-TEM) AR 12. Inner Vessels (IV) Level 2 Manager Meyers (PRI) C 12.1.1 Ar liner mechanical Specifications & method of construction Martoff (TEM) AR 12.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 12.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 12.1.4 Xe liner Reflector, windows Aprile (COL) XE 12.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 12.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 12.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 12.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 13.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 13.2 8" PMT's radioactivity budget Characterization of components Pocar (UMA) AR 13.3.1 Procurement Procurement Arisaka (UCLA) C 13.3.2 Test Test Characterization Arisaka (UCLA) C 13.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 13.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 13.5.2 RPMTs support Mechanical support structure Martoff (TEM) AR 13.5.1 QUPIDs support Mechanical support structure Martoff (TEM) AR 13.5.2 PMTs support Mechanical support structure Martoff (TEM) AR 13.5.3 PMTs signals Thermal management Sonnenschein (FNAL) AR	1.1.8.1	Xe Specific Calibration	Light & charge sources for calibration data	Oberlack (RIC)	XE
1.1.9.2 TPC materials Radon plate-out Monroe (MIT) C 1.1.9.3 TPC materials Radon emanation Pocar (UMA) C 1.1.10.1 XE TPC integration Mechanical & electrical systems integration Tajiri (COL) XE 1.1.10.2 Ar TPC integration Mechanical & electrical systems integration Sands (PRI-TEM) AR 1.2. Inner Vessels (IV) Level 2 Manager Meyers (PRI) C 1.2.1.1 Ar liner mechanical Specifications & method of construction Martoff (TEM) AR 1.2.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMT's radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Martoff (TEM) AR 1.3.5.1 QUPIDs signals Thermal management Sonnenschein (FNAL) AR 1.3.6.1 QUPIDs signals Thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.1.8.2	Ar Specific Calibration	Light & charge sources for calibration data	Monroe (MIT)	AR
1.1.9.3 TPC materials Radon emanation Pocar (UMA) C 1.1.10.1 Xe TPC integration Mechanical & electrical systems integration Tajiri (COL) XE 1.1.10.2 Ar TPC integration Mechanical & electrical systems integration Sands (PRI-TEM) AR 1.2. Inner Vessels (IV) Level 2 Manager Meyers (PRI) C 1.2.1.1 Ar liner mechanical Specifications & method of construction Martoff (TEM) AR 1.2.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 Qupins radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8 PMT's radioactivity budget Characterization of components Oberlack (RIC) C 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 Qupins support Mechanical support structure Martoff (TEM) AR 1.3.6.1 Qupins signals Thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.1.9.1	TPC materials	Radioactivity budgets	Pocar (UMA)	_
1.1.10.1 Xe TPC integration	1.1.9 .2	TPC materials	Radon plate-out	Monroe (MIT)	С
1.1.10.2 Ar TPC integration Mechanical & electrical systems integration Sands (PRI-TEM) AR	1.1.9 .3		Radon emanation	Pocar (UMA)	С
1.2. Inner Vessels (IV)	1.1.10.1	Xe TPC integration	Mechanical & electrical systems integration	Tajiri (COL)	XE
1.2.1.1 Ar liner mechanical Specifications & method of construction Martoff (TEM) AR 1.2.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8° PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8° PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management Sonnenschein (FNAL) AR 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.1.10.2	Ar TPC integration	Mechanical & electrical systems integration	Sands (PRI-TEM)	AR
1.2.1.2 Ar WaveLength Shifter (WLS) TPB films & their application Galbiati (PRI) AR 1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.	Inner Vessels (IV)	Level 2 Manager	Meyers (PRI)	С
1.2.1.3 Ar liner interfaces Interface to TPC electrodes & acrylic CV Sands (PRI-TEM) AR 1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.1.1		Specifications & method of construction	Martoff (TEM)	AR
1.2.1.4 Xe liner Reflector, windows Aprile (COL) XE 1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8° PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8° PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		Ar WaveLength Shifter (WLS)	TPB films & their application	Galbiati (PRI)	AR
1.2.2.1 Xe containment vessel Vessel structure & manufacture Tajiri (COL) XE 1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8° PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8° PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		Ar liner interfaces	Interface to TPC electrodes & acrylic CV	Sands (PRI-TEM)	AR
1.2.2.2 Ar containment vessel Acrylic vessel structure & manufacture Sands (PRI-TEM) AR 1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8° PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8° PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		Xe liner	Reflector, windows	Aprile (COL)	XE
1.2.2.3 Mechanical seals Top & bottom plate seals Sonnenschein (FNAL) C 1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.2.1	Xe containment vessel	Vessel structure & manufacture	Tajiri (COL)	XE
1.2.2.4 HV & HHV seals HV & HHV feedthrough flange seals Wang (UCLA) C 1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.2.2	Ar containment vessel	Acrylic vessel structure & manufacture	Sands (PRI-TEM)	AR
1.2.2.5 Vessels materials Radioactivity budget Pocar (UMA) C 1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.2.3	Mechanical seals	Top & bottom plate seals	Sonnenschein (FNAL)	C
1.3 Photodetector Level 2 Manager Arisaka (UCLA) C 1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		HV & HHV seals	HV & HHV feedthrough flange seals	Wang (UCLA)	C
1.3.1 QUPIDs radioactivity budget Characterization of components Oberlack (RIC) C 1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.2.2.5	Vessels materials	Radioactivity budget	Pocar (UMA)	C
1.3.2 8" PMTs radioactivity budget Characterization of components Pocar (UMA) AR 1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test & characterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.5.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3	Photodetector	Level 2 Manager	Arisaka (UCLA)	С
1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Scharacterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8 PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.1	QUPIDs radioactivity budget		Oberlack (RIC)	С
1.3.3.1 Procurement Procurement Arisaka (UCLA) C 1.3.3.2 Test Test Scharacterization Arisaka (UCLA) C 1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8 PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		8" PMTs radioactivity budget	Characterization of components	Pocar (UMA)	AR
1.3.3.3 Database Database with photosensors characteristics Arisaka (UCLA) C 1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDS support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDS signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.3.1	Procurement		Arisaka (UCLA)	_
1.3.4 Photocathodes Optimization of quantum efficiency Suyama (Hamamatsu) C 1.3.5.1 QUPIDs support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)		Test	Test & characterization	Arisaka (UCLA)	_
1.3.5.1 QUPIDS support Mechanical support structure Wang (UCLA) C 1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDS signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.3.3	Database	Database with photosensors characteristics	Arisaka (UCLA)	С
1.3.5.2 8" PMTs support Mechanical support structure Martoff (TEM) AR 1.3.6.1 QUPIDs signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.4	Photocathodes	Optimization of quantum efficiency	Suyama (Hamamatsu)	
1.3.6.1 QUPIDS signals Thermal management of cable Wang (UCLA) C 1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)					_
1.3.6.2 PMTs signals Cabling & thermal management Sonnenschein (FNAL) AR 1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.5.2				AR
1.4 Cryogenic Systems (CS) Level 2 Manager Wang (UCLA)	1.3.6.1				_
ery game cycles (sey	1.3.6.2	PMTs signals	Cabling & thermal management	Sonnenschein (FNAL)	AR
	1.4	Cryogenic Systems (CS)	Level 2 Manager	Wang (UCLA)	
	1.4.1	Cooling Elements	Specifications & design	Haruyama (KEK)	C

MAX

responsibilities



1.4.2.1	LXe fill	Fill, empty, & purification of LXe	Giboni (COL)	XE
1.4.2.2		Fill, empty, & purification of inner LAr	Pordes (FNAL)	AR
1.4.2.3		Fill, empty, & purification of outer LAr	Pordes (FNAL)	AR
1.4.3.1		SS double-walled cryostat	Sonnenschein (FNAL)	AR
1.4.3.2		OFHC double-walled cryostat	Tajiri (COL)	XE
1.4.5.1		HV, signal, fluid feedthroughs	Sonnenschein (FNAL)	AR
1.4.5.2		HV, signal, fluid feedthroughs	Giboni (COL)	XE
1.4.6		Support & leveling	Sonnenschein (FNAL)	C
		Steady-state & emergency cooling systems	Sonnenschein (FNAL)	Č
		Common fill, empty, storage systems	Sonnenschein (FNAL)	č
		Ar fill, empty, storage systems	Sonnenschein (FNAL)	AR
1.4.8.3		Xe fill, empty, storage systems	Lopes (COI)	XE
1.4.9	CS mechanics	Mechanical interfaces of all vessels	Sonnenschein (FNAL)	С
1.4.10	CS materials	Radioactivity budget & 222Rn emanation	Pocar (UMA)	С
1.4.11	Recovery systems	Zero-boiloff gas/liquid recovery	Wang (UCLÁ)	С
1.5	Pre-Purification (PP)	Level 2 Manager	Galbiati (PRI)	С
1.5.1	Depleted argon collection	Engineering of collection system	Fitch (Linde)	AR
1.5.2	Cryogenic distillation of Ar & Xe	Engineering of cryogenic distillation column	Fitch (Linde)	С
1.6	Runtime Purification (RP)	Level 2 Manager	Pordes (FNAL)	С
1.6.1.1	Filters	Selection of filters & getters	Weinheimer (MUN)	С
1.6.1.2	Ar specific filters	Selection of Ar specific filters & getters	Galbiati (PRI)	AR
1.6.1.3	Filters	Selection of filters & getters	Weinheimer (MUN)	XE
1.6.2.1	Ar RP scheme	Fluid handling & control	Pordes (FNAL)	AR
1.6.2.2	Xe RP scheme	Fluid handling & control	Aprile (COL)	XE
1.6.3 .1	RP materials	Radioactivity budget & 222Rn emanation	Weinheimer (MUN)	С
1.6.3.2	RP materials	Radioactivity budget & 222Rn emanation	Pocar (UMA)	С
1.6.4.1	CRDS Enginering	Ultra-trace measurement of N2, O2, & H2O	Lehmann (UVA)	C
1.6.4.2	CRDS Operations	Procedures & protocols	Zehfus (BHSU)	С
1.7	Flectronics	Level 2 Manager	Chou (ENAL)	С
	Electronics Voltage amplifiers	Level 2 Manager	Chou (FNAL) Arisaka (UCLA)	C
1.7.1	Voltage amplifiers	QUPIDS & PMTs	Arisaka (UCLA)	С
1.7.1 1.7.2	Voltage amplifiers Digitizer layout	QUPIDS & PMTs Specifications & design	Arisaka (UCLA) Arisaka (UCLA)	C
1.7.1 1.7.2 1.7.3	Voltage amplifiers Digitizer layout Digitizer FPGA firmware	QUPIDS & PMTs Specifications & design Specifications & code development	Arisakà (UCLÁ) Arisaka (UCLA) Hungerford (HOU)	C C
1.7.1 1.7.2 1.7.3 1.7.4	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU)	C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL)	C C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL)	C C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU)	C C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7 1.7.8	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls GPS Clock	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment Specifications & design	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU) Hungerford (HOU)	C C C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7 1.7.8 1.7.9	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls GPS Clock Crates & racks	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment Specifications & design Specifications	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL)	C C C C C
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7 1.7.8 1.7.9	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls GPS Clock Crates & racks DAQ	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment Specifications & design Specifications Level 2 Manager	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Hungerford (HOU)	C C C C C C C C C C C C C C C C C C C
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1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7 1.7.8 1.7.9 1.8 1.8.1 1.8.2	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls GPS Clock Crates & racks DAQ Communications Links Computers	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment Specifications & design Specifications Level 2 Manager Specifications & protocols Specifications	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU) Pordes (FNAL) Hungerford (HOU) Purdes (FNAL) Hungerford (HOU) Alton (AUG)	
1.7.1 1.7.2 1.7.3 1.7.4 1.7.5 1.7.6 1.7.7 1.7.8 1.7.9 1.8 1.8.1 1.8.2 1.8.3	Voltage amplifiers Digitizer layout Digitizer FPGA firmware 2 nd level DAr trigger board HV supply Cables Slow Controls GPS Clock Crates & racks DAQ Communications Links Computers On-Line Software	QUPIDS & PMTs Specifications & design Specifications & code development Specifications & design QUPIDS & PMTs QUPIDS & PMTs Monitoring of electronics & environment Specifications & design Specifications Level 2 Manager Specifications & protocols Specifications Specifications Specifications Specifications	Arisaka (UCLA) Arisaka (UCLA) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Sonnenschein (FNAL) Hungerford (HOU) Hungerford (HOU) Pordes (FNAL) Hungerford (HOU) Hungerford (HOU) Hungerford (HOU) Hungerford (HOU) Alton (AUG) Hungerford (HOU)	
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More MAX responsibilities



Depleted Argon:

Present 5% of atmosphere limit set by test volume (at Bern)

Harvesting from CO₂ wells (Princeton)

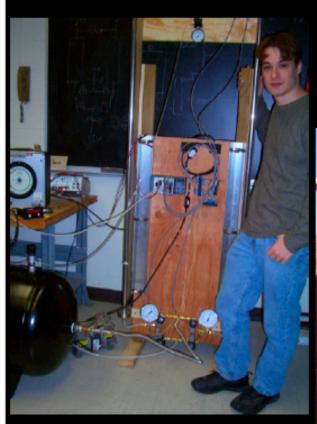
Aim is characterization to < 1% of atmospheric rate (Fermilab and Princeton)

Fermilab using high pressure (180 bar) ionization chamber of OFHC copper with muon veto and hermetic lead-shielding in NuMI tunnel



Depleted Argon harvesting (Princeton)

Discovery of underground sources of low-activity argon



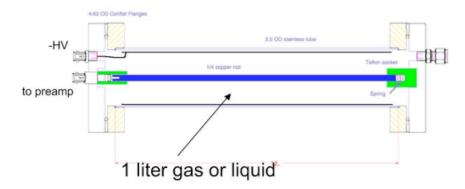
Prototype Purification Plant at Princeton
Sampling on a gas field in the West



Funded by NSF

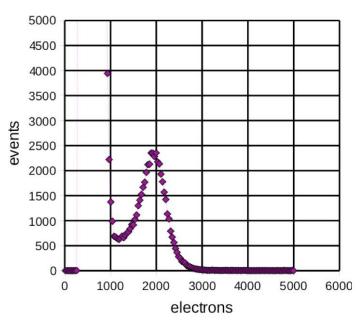


Prototype Ionization Chamber Work (8.5 bar)





60 keV X-rays (241-Am) in 8.5 Bar Argon



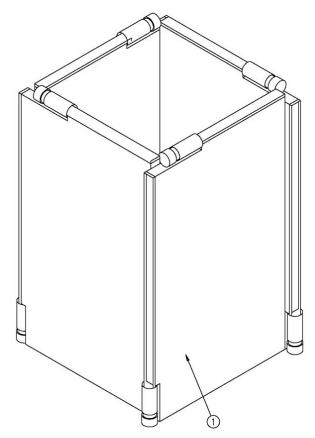
220 electrons rms noise

³⁹Ar spectrum flat to 560 keV 560 keV ~ 20,000 electrons



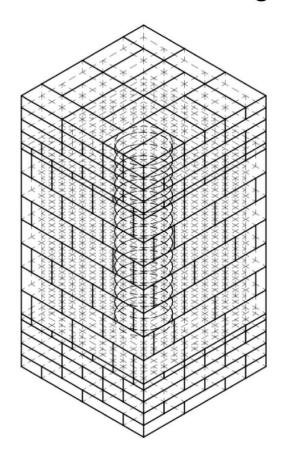
Muon Veto Drawing

Lead Shield Drawing



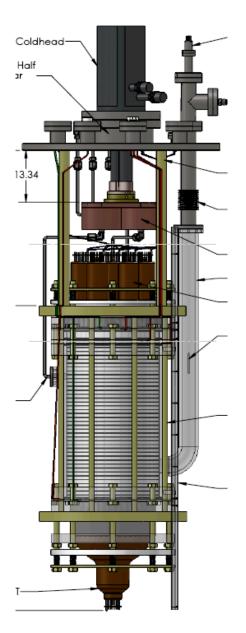
Ion Chamber Body





Muon veto, lead shield, and low-radioactivity copper, and running in NuMI tunnel needed to achieve < 0.01 Bq/kg





20 kg Innards

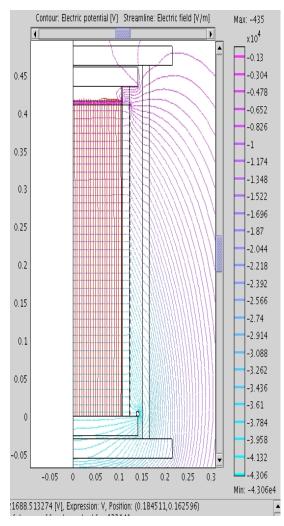
more What:

20 kg device at Princeton - inner TPC with depleted Argon surrounded by normal Argon

R & D on:
light-collection,
TPC design,
PMTs (new from Hamamatsu),
bases,
electronics readout,
depleted Argon

Fermilab supplying:
PMT bases,
HV feedthroughs,
TPC electrostatics design

TPC Drift-field Lines



(C.J. Martoff (guest))



Next two years:

Build, run, study 20 kg device

Characterize depleted Argon

Develop data acquisition (with CD - triggerless DA)

R & D on light collection (wave-shifter, coatings, optics)

High-level responsibilities for Electronics, Cryogenics and Purification in S4 proposal

Develop and present proposal for intermediate (~500 kg) device as prototype for MAX (full Argon mechanical system - partial coverage with PMTs(?))

August 7 2009



Back-ups

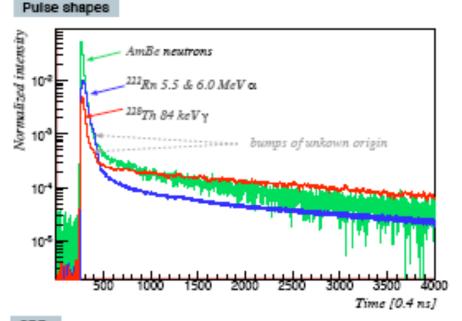


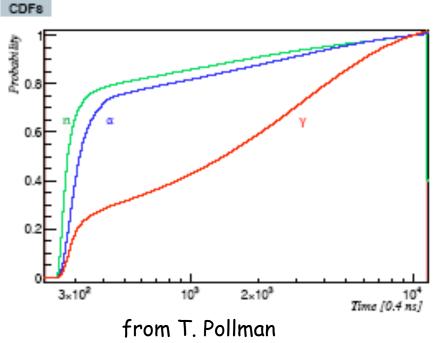
Time distribution of light* output from Liquid Argon for γs , αs and neutrons

2 components: $\tau(\text{fast}) = 7 \text{ ns}$ $\tau(\text{slow}) = 1600 \text{ ns}$

I(fast)/I(slow) = $0.3(\gamma)$ = $1.0(\alpha)$ = 3.0(neutrons)

*convolved with waveshifter and PMT response



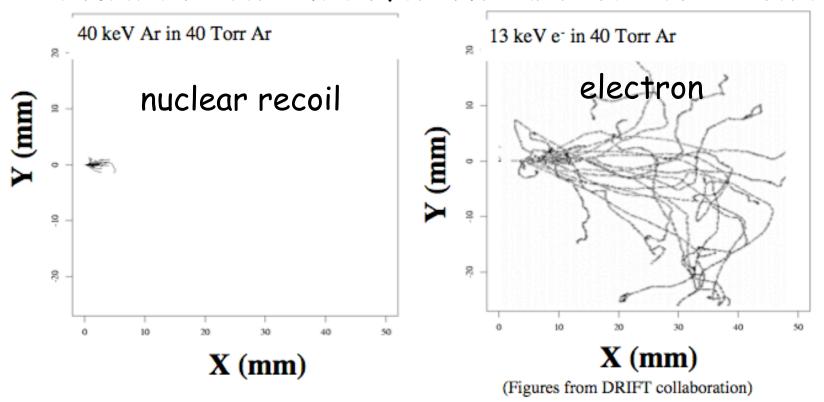




Discriminating Against Backgrounds

- WIMPs interact with the nucleus, while most backgrounds are due to electron scattering by gamma and beta rays.
- The resulting spatial distributions of energy and charge are very different-- this is fundamental physical basis of most discrimination techniques.

Ionization distribution for nuclear recoil and electron



Connections between different devices



